A Structural Decomposition Analysis of CO2 Emission in China: 2002-2007

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Abstract

This paper provides a computation on both the China's aggregate CO2 emission volume and the emission of each sector over the period of 2002-2007, based on the input-output analysis. Further analysis is also given on the various determinants of the change in the emission volume, with the aid of structural decomposition approach based on a residual-free method. The changes in emission are analyzed in terms of five different factors. Among the five factors studied in the paper, it is found that emission intensity and domestic need are the main reasons for the decrease in emission, while production technology, trade structure and scale effect are the more significant causes to the increase in emission. It is also observed that although the direct emission intensity decreases during the study period, the complete emission intensity remains unchanged, which reflects the result of energy policy unequal in different sectors.

Keywords

Carbon Emissions; Input-output Table in Hybrid Units; Structural Decomposition Analysis; Structural Change

Introduction

Much debated issues over carbon emission throughout the last decade, concerning the global warming along with its environmental challenge, have brought up an increasingly interesting topic for the researchers over the world, and also led to an sharply intensified research on CO2 emission in China in recent years.

Since the beginning of economic reform in 1979, China has experienced rapid economic growth, with its GDP growth at an average of 9.9% annually over the period from 1979 to 2009. Despite the exterior shock from the financial crisis in 2008, China still managed to expand its economy size at 10.7% annually on average over the period from 2001 to 2009. During the same period, China's energy consumption soared at an even faster pace to have increased by an average annual rate of 11.8%, from 1518.0 Mtce in 2002 to 2655.8 Mtce in 2007. It is estimated that energy related CO2 emission of China grew by 59% in the period of 2000-2004 which accounted for about 56% of the increase in the global CO2 emission. The issue has not just declined academic interest but raised official concern as well in China. As a result, Chinese government, for the first time in its latest Five-Year Plan (2011-2015), mandated the reduction in energy intensity as national development objective, and even detailed and quantified the objective on provincial level.

There already exist many literatures addressing the energy intensity of the GHGs, but seldom do they delve into the topic of absolute indicator of emission, which is approached in this paper employing the tools of input-output model and structural decomposition analysis.

Literature Review

To understand the historical changes in economic, environmental, employment or other social-economic indicators, it is necessary to make assessments of the driving forces behind these changes. Two major techniques to decompose indicator changes on the sector level are Structural Decomposition Analysis (SDA) and Index Decomposition Analysis (IDA) both of which apply the index theory to decomposition and the basic differences between them are the fundamental data required and the effect of decomposition.

Dietzenbacher & Los(1998) combined the bipolar decomposition with input-output analysis and broke down the emission into three factors: energy intensity, production technique and economy scale. Zhang(2003)

resorted to Laspeyres approach to merge the China's industries of 1990-1997 into 29 separate sectors, and decomposed the use of energy into three factors: scale effect, production technique and structure effect. His finding is that production technique is the most important factor among the three.

In brief, the investigation on the current literatures reveals the three different approaches to energy emission decomposition: first of all, to emphasize on analysis of the indicators in relative forms; secondly, to decompose the emission into four factors: energy intensity, production technique, structure and economy scale; thirdly, to study the basis of Divisia index and various other indices. By contrast, this paper focuses on the volume of carbon emission, which is an indicator in absolute form as well as incorporates five decomposed factors: energy intensity, production technique, domestic demand structure, trade structure and economic scale, in which the trade structure effect can be more persuasive in explaining the embodied carbon emission in China. At last, the two-polar decomposition method has been used in the decomposition procedure.

This paper is organized as follows. In the next section, the IPCC method to calculate the CO2 emission is described, and the proposed decomposition approach to decompose the change of CO2 emission over time is employed. The sector disaggregation and data used are discussed in Section 3. The analysis and some main results are presented in Section 4. In Section 5, conclude is made on this study.

Methodology and Data

Caculation of CO2 emission

Based on the basic input-output model, the total social product and the final demand can be linked with the direct consumption coefficients matrix :

$$X=(I-A)^{-1}y$$

Where u is known as the structure or composition effect of final demand, i.e. the percentage of every commodity in a respective final demand category. y is a scalar which captures the changes in total volume demand.

If the carbon emission intensity vector is denoted as f , and the volume of carbon emission as C , we have:

$$C=fX=f\left(I-A\right)^{-1}y=fDy$$

In order to study the effect of trade on the carbon emission, final demand is broken down as:

$$y=\sum_i\frac{y_i}{y}y=\sum_i\frac{y_{i,dom}}{y}\left(1+\frac{y_{i,row}}{y_{i,dom}}\right)y \ =\sum_i y_{i,m}\times y_{i,c}\times y$$

Where y_m is also known as the structure or composition effect of final demand, i.e. the percentage of every commodity in a respective final demand category, $y_{i,c}$ gives the proportion of every category within aggregate final demand; and y is a scalar which captures the changes in total volume demand.

By the denotations above, the volume of emission can be expressed as:

$$C=fD\tilde{y}_m\tilde{y}_c y=\sum_i\sum_j f_i d_{ij} y_{m,i} y_{c,i} y \ ,$$

The second stage is to decompose the change of C into five effects:

$$\Delta C=f_t D_t\tilde{y}_{mt}\tilde{y}_{ct}y_t-f_0 D_0\tilde{y}_{m0}\tilde{y}_{c0}y_0 \ ,$$

⊿ implies the change of the corresponding variable, and 0 and t implies the period of base and report. Using the two-polar decomposition method recommended by Dietzenbacher & Los(1998).

The five decomposition factors are carbon emission intensity effect, domestic demand effect, trade structure effect and economy scale effect. They can be calculated by the formulas below.

$$\Delta C_f=\frac{1}{2}[\Delta fD_t\tilde{y}_{mt}\tilde{y}_{ct}y_t+\Delta fD_0\tilde{y}_{m0}\tilde{y}_{c0}y_0]$$

$$\Delta C_d=\frac{1}{2}[f_0\Delta D\tilde{y}_{mt}\tilde{y}_{ct}y_t+f_t\Delta D\tilde{y}_{m0}\tilde{y}_{c0}y_0]$$

$$\Delta C_{y_m}=\frac{1}{2}[f_0 D_0\Delta\tilde{y}_m\tilde{y}_{ct}y_t+f_t D_t\Delta\tilde{y}_m\tilde{y}_{c0}y_0]$$

$$\Delta C_{yc}=\frac{1}{2}[f_0 D_0\tilde{y}_{m0}\Delta\tilde{y}_c y_t+f_t D_t\tilde{y}_{mt}\Delta\tilde{y}_c y_0]$$

$$\Delta C_{yl}=\frac{1}{2}[f_0 D_0\tilde{y}_{m0}\tilde{y}_{c0}\Delta y+f_t D_t\tilde{y}_{mt}\tilde{y}_{ct}\Delta y]$$

Data Source

The data are collected from China Statistical Yearbook (CSY) and China Energy Statistical Yearbook (CESY). In light of the price change over the period, adjustment is made to the 2007 data after compared with the price indices from 2002 to 2007, using the method by Liu(2010). The price indices come from the Chinese statistical yearbook 2003-2008.

When comparing the emission changes during the period, we merge the economy into 29 sectors. The sectors and their corresponding codes are presented in table 1. The study takes into consideration four major types of energy, including primary energy, secondary energy, electricity and heat, data of which can be also found in the CESY.

TABLE 1 INDUSTRY SECTORS AND THE CODES.

Code	Sectors
1	Agriculture
2	Coal mining, washing
3	Petroleum and Natural Gas extraction
4	Metal ores mining
5	Non metal ores mining
6	Manufacture of Foods and tobacco
7	Manufacture of Textile
8	Manufacture of Textile Wearing
9	Processing of Timbers
10	Papermaking, Printing
11	Processing of Petroleum, Coking
12	Chemical Industry
13	Manufacture of Nonmetallic Products
14	Smelting and Rolling of Metals
15	Manufacture of Metal Products
16	Manufacture of General Machinery
17	Manufacture of Transport Equipment
18	Manufacture of Electrical Machinery
19	Manufacture of Communication Equipment
20	Manufacture of Measuring Instrument
21	Manufacture of Artwork, Other Manufacture
22	Waste
23	Electricity and Heat
24	Gas Production
25	Water Production
26	Construction
27	Traffic, Transport and Storage
28	Wholesale and Retail Trades
29	Others

Results and Analysis

The Driving Forces: from the Decomposition View

Based on the calculation of the energy input-output table, the volume of China's carbon dioxide emission is estimated to have grown from 2887.3 million ton in 2002 to 5664.6 million ton in 2007, at an average annual rate of 13.3%, slightly faster than 11.6% of China's average GDP growth rate over the same period.

TABLE 2 DECOMPOSITION OF CARBON EMISSION

	ΔC	ΔC_f	ΔC_d	ΔC_{y_m}	ΔC_{y_c}	ΔC_{y_l}
Change of Emission [million ton]	2812.0	-2321.1	1718.4	-9901.9	980.7	12335.9
ratio(%)	100	-82.5	61.1	-352.1	34.8	438.7

Table 2 demonstrates the decomposition of the total volume of carbon dioxide emission and the four factors affecting the change of emission: carbon emission intensity, production technique, structural change and economy scale.

The following conclusions can be drawn from Table 2:

Firstly, in comparison to 2002, the emission level of 2007 dropped sharply due to the change of emission intensity and domestic demand as the positive factors in carbon emission reduction. Emission intensity accounts for 82.5% of the change, which reflects the improvement of efficiency in energy use during the period, and the structure of demand contributes 327% reduction to the total change.

Secondly, the growth of economic scale makes a contribution of 438.7% to the total change of emission, hence the primary determinant, which implies that the expansion of economy is the main cause of the environmental pollution and the overexploitation of natural resources. It also reflects the fact that industrial structure has not upgraded as quickly as the economy has grown.

Thirdly, the change of production technique increases the carbon dioxide emission, which almost offsets the effect of the positive factors as the first statement shows.

The Trading Structure Effect to the Changes of Emission

The change of carbon dioxide emission of sectors is analyzed to find that each sector has different sensitivity to the five factors. Emission intensity, production technique and economic scale have similar effects on every sector, so the emphasis is put on the other two factors in the next paragraph.

During 2002-2007, domestic demand structure reduced the emission on the following sectors: Smelting and Rolling of Metals, textiles, agriculture and construction are the sectors. While the manufacture of great equipment, extraction of petroleum and natural gas, transportation, storage and telecommunication sectors' emission increased significantly attributed to this factor.

The distribution of net export in different sectors reflects the trade structure of the economy. As shown in Table 3, during the period of 2002-2007, extraction of petroleum and natural gas, mining of metal ores, mining of nonmetal ores had performed large scale of import, which reduced the emission of CO2 in these sectors. Agriculture, wholesale and retail trades, catering services had similar performance. While the

sector of smelting and rolling of metals had changed net import to net export during the period, resulting in mass emission of CO2. The other four sectors had increased their net exports during the period, leaving mass emission in domestic realm. In conclusion, the characteristic of China's trade structure is the main reason of emission growth. This character verifies the hypothesis of "polluted heaven".

TABLE 3 TRADING STRUCTURE EFFECT BY SECTOR

	Trading structure effect [million ton]
Extraction of Petroleum and Natural Gas	-114.9
Mining of Metal Ores	-22.7
Mining of Nonmetal Ores	-22.4
Agriculture, Forestry& Fishery	-22.1
Wholesale and retail trades and services	-18.8
Manufacture of General Machinery	70.7
Manufacture of Nonmetallic Mineral Products	85.5
Manufacture of Communication Equipment	131.8
Textiles	272.9
Smelting and Rolling of Metals	809.9

The Emission Intensity Analysis

When it comes to judge the effect of an energy policy, we should consider not only the reduction of a certain sector's emission, but also the effect on the other sectors. The total emission intensity (TEI) is calculated to reflect this indirect relationship between sectors. Figure 1 shows the change of total emission intensity (TEI), direct emission intensity (DEI) and indirect emission intensity (IEI) during 2002-2007.

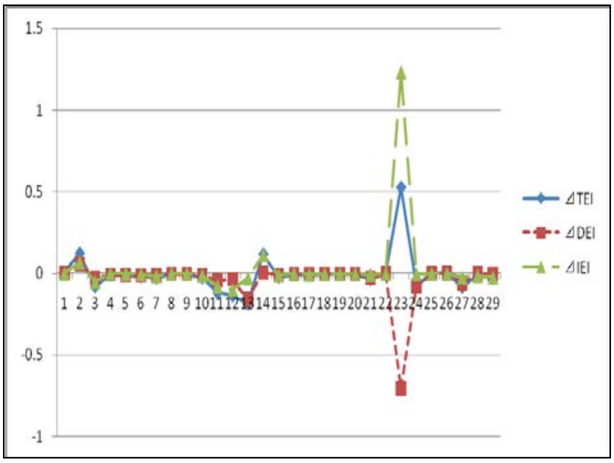

FIG 1 THE CHANGE OF EMISSION INTENSITY (2002-2007)

Using the weight of total products, we have the weighted average of emission intensity. During the year 2002-2007, the average of DEI decreased from 0.092 kg/RMB to 0.0739 kg/RMB, while the average of TEI increased from 0.352 to 0.424, with an average annual rate of 3.8%. This implied that the indirect consumption among different sectors cannot be neglected, especially in the establishment of an energy policy.

During 2002-2007, although most sectors' emission intensity decreased, some sectors' condition did not improve. This reflects that the energy policy did not have similar effects on the sectors.

Conclusions

This study tried to analyze the carbon dioxide emission in China during 2002 to 2007. The model used for this analysis is the familiar input–output model extended to cover carbon emission. For decomposition of the sources of change in emissions over the period, a residual-free composition method has been applied. The method factorizes total change in emissions over the period into five contributive components, emission intensity, production technique, domestic demand, trade structure and size of the economy.

According to our analysis, it was found that the energy use during 2002-2007 grew rapidly, compared with the results by Ming Z. (2009). According to SDA, it is revealed that energy intensity and domestic demand structure are the main reason of the reduction of carbon emission. Economic Scale is the most important factor that increases the carbon emission. Because the character of the foreign trade of China, the net export of high carbon emission industry produces much more carbon dioxide when compared to the carbon emission increased sharply during the period.

Our results show that the change of demand structure is the major source of China's decrease of emission over the period. This result is quite different from the results of Huang(1993), Sinton & Levine(1994), Zhang(2003). Moreover, the change of production technique is the major source of China's increase of emission, which is different from the results of Chung and Rhee (2001). The results reflect the complicate situation in China on the control of carbon emission.

Finally, although the DEI decreased during 2002-2007, the TEI increased with the average rate of 3.8%. The driving force may be the result that some sectors increase the indirect emission during production. These include the sectors of electric power and heat, agriculture, smelting and rolling of metals, mining and

washing of coal, which should be given more emphasis in the establishment of energy policy.

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